DOCKET NO.: 4532
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TITLE OF THE INVENTION

Method for Using Water In the Processing of Fuels for High Temperature Fuel Cells

PRIORITY CLAIM

This application is based on and claims the priority under 35 U.S.C. §119 of German Patent Application 102 29 309.0, filed on June 29, 2002, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to a method for using water, primarily wastewater, such as black water and/or gray water, in the processing of fuels for high temperature fuel cells.

BACKGROUND INFORMATION

In the following text the term "black water" refers to water that has been contaminated with any kind of filth, including residue, refuse, feces, and so forth, including gray water. The term "gray water" includes water which exits from water supplying

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EV 338 198 249 US
JUNE 30 2003

systems or drinking water systems and is only slightly contaminated, for example, used wash water such as hand wash water. The term "wastewater" includes both gray water and/or black water.

Fuels with long chemical bonding chains based on hydrocarbons such as diesel fuel, kerosene, petroleum, and gasoline can be used in high temperature fuel cells because internal reformer processes take place in these fuel cell types. These internal reformer processes make these conventional fuels suitable for use in the energy production process in the fuel cell. For increasing the efficiency, such fuels should be pretreated before being supplied to the fuel cell or cells. For particular applications or types of use it is desirable to subject these fuels to an additional processing with water.

On board of aircraft and other mobile conveyances or in remote stationary facilities, water becomes available in the form of wastewater resulting from the use of the water supply by people. Fuel cells can be used, not only in their function for producing energy, but also for generating fresh water. For this purpose it is necessary to gain or recover sufficient quantities of free hydrogen molecules for the process that proceeds in the fuel cell. These hydrogen molecules can be supplied by fuels based on hydrocarbons. However, water may also be a source for providing hydrogen molecules. In a special case even wastewater can be used as a hydrogen molecule source.

OBJECTS OF THE INVENTION

In view of the foregoing it is the aim of the invention to achieve the following objects singly or in combination:

to take advantage of the fact that liquid hydrocarbon fuels and water are substantially easier to store than hydrogen, especially liquid hydrogen;

to process black water and gray water as a source of hydrogen molecules for use in high temperature fuel cells, whereby the wastewater must be sufficiently precleaned to make it suitable for use in a high temperature fuel cell;

to supply an emulsion of hydrocarbon liquid fuel and water to a high temperature fuel cell where the emulsion is exposed to a reformer process for separating hydrogen molecules from the emulsion;

to arrange the stages in line so that a continuous supply of optimal quantities is made available directly next to the fuel cell; and

to reduce the weight of the equipment needed, for example on board of an aircraft, by reducing the size of the wastewater storage facilities and by using at least some of the wastewater for the production of hydrogen molecules.

SUMMARY OF THE INVENTION

The above objects have been achieved according to the invention by the combination of the following steps:

a) using as a fuel for a high temperature fuel cell a liquid hyrocarbon fuel, preferably kerosene;

b) processing wastewater by one or more steps of filtration, reverse osmosis, and equivalent treatments to produce prepared water; and

c) emulsifying said liquid hydrocarbon fuel with the prepared water to form an emulsion as fuel for the high temperature fuel cell.

By processing or pretreating the wastewater a non-critical use of wastewater can be achieved in a high temperature fuel cell.

Following the important emulsifying operation, the process according to the invention preferably includes a desulfurization process and a cracking process for the separation of the hydrogen molecules from the emulsion, whereby the second and third stages, namely the desulfurization and the cracking preferably take place in separate compartments or individual housings within the enclosure of the fuel cell.

The first stage is based on the principle of emulsifying two liquids by mechanical energy, which liquids are not actually mixable, whereby the liquid components in the emulsion are finally and uniformly distributed in the emulsion. According to

the invention a hydrocarbon fuel, for example kerosene is emulsified with water in an ultrasound field introduced into an emulsifier container.

The emulsifying stage is preferable followed by an electrochemical process when the emulsion has reached the required electrical conductivity, for example at least 600 μS (micro Siemens). This electrochemical process involves a precracking of the fuel. A so-called gap-electrolysis is suitable for separating the carbon links. This precracking is performed preferably between two concentric cylinders such as two pipes concentrically arranged one within the other, whereby chemical links of organic molecules of hydrocarbons and carbons are cracked out of the used or wastewater. These organic compounds are thereby separated into their initial atoms.

A catalytic process follows the precracking process, whereby sulfur, sulfur compounds including hydrogen sulfide as well as other contaminants are separated from the fuel. The third stage involves the introduction of thermal energy into the emulsion for cracking long chain hydrogen carbons into shorter chains. This cracking is performed to the extent possible by suitable conventional methods in order to convert long chain hydrocarbons into shorter chain links.

In high temperature fuel cells such as SOFCs (Solid Oxide Fuel Cells) it is possible to use various kinds of fuels as a hydrogen supplier at the anode side of the high temperature fuel cell due

to the internal reformation processes that are typical for high temperature fuel cell operations. However, for reasons of efficiency, it is preferred to use fuels which have short hydrocarbon chains. Long chain hydrocarbons should thus be pretreated for their use in high temperature fuel cells to reduce the chain link or bond lengths. The addition of water enhances or supports the internal reforming processes on the one hand, while on the other hand wastewater quantities may be used which, after pretreatment are regenerated by the internal reforming processes of the high temperature fuel cell.

It is advantageous that long chain hydrocarbon fuels, such as kerosene, are available in mobile conveyances such as commercial aircraft. Such fuels are to be mixed or rather emulsified with water for the use of these fuels in high temperature fuel cells. Advantageously the water quantities that become available on board as wastewater can be prepared by a pretreatment such as filtration, for supplying sufficient pretreated wastewater quantities for the preparation of fuel for use in a high temperature fuel cell, thereby reducing the need for larger storage facilities for the wastewater. The filtration of the wastewater must remove solid components. The degree of the water quality achievable by filtration is of a secondary importance for the use of such water for regeneration in a fuel cell. The most important advantages of the present method are seen in the weight reduction which has a direct influence on the fuel consumption of an aircraft and in the need for substantially smaller wastewater storage resulting a further weight reduction and gain

of space in an aircraft. Any remaining quantities of wastewaters are also substantially smaller and hence enhance the servicing of the aircraft on the ground.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be clearly understood, it will now be described in detail in connection with example embodiments thereof, with reference to the accompanying drawing in which the single Figure shows a block diagram of an apparatus for performing the present method in combination with a high temperature fuel cell.

DETAILED DESCRIPTION OF A PREFERRED EXAMPLE EMBODIMENT AND OF THE BEST MODE OF THE INVENTION

The single Figure shows a high temperature fuel cell 10 having its own enclosure 4. A block diagram 20 illustrates schematically the emulsifying process for using wastewater to provide an emulsified fuel for the fuel cell 10. Fuel 8 is fed through a dosing pump 6 into an emulsifying container 1. Simultaneously, prepared wastewater 9 is fed through a dosing pump 7 into the same or common container 1. A sound frequency generator 5 supplies the emulsifying energy into the housing 1. A generator known to as a "Sonotrode" may be used, for example. It is preferred to feed the fuel 8 and the wastewater 9 into the container 1 directly in front of the "Sonotrode 5", which is driven by a power source 5A.

Upstream of the water dosing pump 7, the water 9 is passed through a cleaning station 15 that may involve one or more filtrations and/or a reverse osmosis process or any other cleaning operation that provides a prepared water suitable or uncritical for the emulsifying process. The prepared water from the station 15 and the fuel 8 are continuously fed into the common reaction container 1. The emulsion is thus also continuously discharged from the container 1. The emulsion is preferably but not necessarily supplied to an electrochemical processing station 16. A separation of molecular bonds of the organic compounds in the emulsion is performed in station 16.

The emulsion is then fed from the electrochemical processing station 16 through a non-return check valve 12 into a housing 2A which is mounted within the enclosure 4 of the high temperature fuel cell 10. A desulfurization process 2 is performed in the housing 2A, whereby thermal energy of the fuel cell 10 is used for the desulfurization of the emulsion. The desulfurization removes sulfur and sulfur compounds including hydrogen sulfide from the emulsion. The sulfur and sulfur compounds are discharged from the fuel cell through a discharge port 11.

Downstream of the desulfurization process 2 a thermal cracking process 3 takes place in a separate housing 3A which is also contained in the enclosure 4 of the fuel cell 10. Here again the thermal energy available in the high temperature fuel cell 10 is used for cracking the emulsified fuel. In addition to the thermal energy provided by the fuel cell 10, the pressure

generated by the dosing pumps 6 and 7 and a catalyst are used for cracking the emulsified fuel.

Following the just described process steps, the fuel that is now in a gaseous state, is supplied to the anode side of the high temperature fuel cell 10. The supply pressure is thereby dependent on the supplied fuel quantity and on the applied or introduced thermal energy. The fuel supply pressure can be controlled in closed loop fashion by the fuel quantity and by the mixture proportions. The mixing ratio as well as the quantities of fuel 8 and water 9 are controlled in closed loop fashion by a control unit 13 which receives at its input emulsion information from a sensor 14 through a link 14A that may be a conductor or a wireless link. The sensor 14 may be an optical sensor which generates a control signal based, for example, on the turbidity and/or on a color stain distributed in the emulsion. In addition or instead, the sensor 14 may measure the electrical conductivity of the emulsion in the emulsifier container 1. The conductivity should be at least 600 μS. The signals provided by the sensor 14 are processed by the control unit 13 such as a CPU, to provide control signals to the pump 6, to the power supply 5A and to the pump 7 as indicated by the respective dashed lines with their arrow heads to provide a closed loop control. Additionally, control parameters such as the water to fuel ratio may be stored in a memory of the CPU 13 and used in a control program.

The pumps 6 and 7 are positive feed non-return pumps, for example gear wheel pumps, that prevent any backflow of fuel and of prepared water. Even if these pumps are intentionally switched off or in case of a power failure, no reflow nor any bypass flow of the fuel and/or water will occur. These pumps 6 and 7 provide a special safety feature in case the high temperature fuel cell 10 must be switched off in an emergency, because by switching off the fuel pump 6 and the sound wave generator 5, water 9 may be pumped by the pump 7 into the now shut-off fuel cell 10 for example if that cell became thermally uncontrollable. The dosing fuel pump 6 will be shut-off first and then the pump 7 may be operated at its maximum capacity for supplying cooling water into the fuel cell through the non-return valve 12 positioned in the enclosure 4 of the fuel cell 10. This non-return or check valve 12 makes sure, in an emergency, that ignited fuel in the cell 10 cannot burn through back into the emulsifying system 20.

The emulsifying system 20, the desulfurization station 2, and the cracking station 3 are preferably installed in a redundant fashion for each fuel cell, so that the fuel cell can continue to receive the emulsion fuel even if one of the system components and/or stations should have failed.

The emulsifying station with its container 1 is preferably equipped with an emergency shut-off (ES) especially for the fuel pump 6. The precracking or removal of the molecular bindings in the emulsion in station 16 should take place at a voltage of about 10 volts between the concentrically arranged pipes that

perform the gap-electrolysis. This voltage may be available directly from the high temperature fuel cell 10.

Incidentally, the pretreatment of the water in the station 15 is performed only to the extent necessary for the emulsification to make this operation uncritical.

Although the invention has been described with reference to specific example embodiments, it will be appreciated that it is intended to cover all modifications and equivalents within the scope of the appended claims. It should also be understood that the present disclosure includes all possible combinations of any individual features recited in any of the appended claims.